Claims

1. A system for performing a virtual colonoscopy comprising:

(a) a digital image generating system;

(b) a storage device, coupled to said digital image generating system, said storage device for storing digital images; and

(c) a digital bowel subtraction processor coupled to receive images of a colon from said storage device, said digital bowel subtraction processor for processing the received digital images of the colon to digitally remove the contents of the colon from the image.

2. The system of Claim 1 further comprising:

an automated polyp detection processor coupled to receive images of a colon from said storage device, said automated polyp detection processor for processing the received digital images of the colon to detect polyps in the colon image.

3. The system of Claim 1 wherein said automated polyp detection processor processes images from which bowel contents have been removed by said digital bowel subtraction processor.

4. The system of Claim 1 wherein said digital bowel subtraction processor corresponds to a raster digital bowel subtraction processor.

5. The system of Claim 4 wherein said raster digital bowel subtraction processor comprises:

a threshold circuit for assessing whether absolute threshold values have been crossed and the ratio at which they have been crossed;

an analysis kernal to scan across images and apply threshold values in a predetermined logic sequence;

means for selecting a starting pixel;

means for selecting a direction to apply a threshold;

a threshold application means; and

a pixel reset means.

6. The system of Claim 1 wherein said digital bowel subtraction processor corresponds to a gradient processor digital bowel subtraction processor.

7. The system of Claim 6 wherein said gradient processor digital bowel subtraction processor comprises:

a threshold circuit for defining a soft tissue threshold value, an air threshold value and a bowel threshold value;

a mask processor for marking elements above the bone threshold value;

a gradient processor for applying a air and bowel threshold values to appropriate regions wherein said gradient processor forms a first mask to capture a first shoulder region in a region corresponding to a transition between air and bowel;

a dilation processor for identifying a second shoulder region in the region corresponding to a transition between air and bowel;

a subtractor for subtracting the combined masks from the gradient processor to leave a desired image.

8. The system of Claim 2 wherein said automated polyp detection processor comprises:

a segmentor to extract pixels in a region which includes a boundary between soft tissue and air in the colon;

a rolling ball processor; and

a vector processor for computing a ratio along a travel path and comparing the travel path to a threshold value.

9. The system of Claim 2 wherein said automated polyp detection processor comprises:

a convolution processor for performing a convolution between a test polyp and a region under test, to indicates the similarities between the region under test and the test polyp.

10. Thy system of Claim 9 wherein said convolution processor generates a correlation matrix and wherein the convolution polyp detector further comprises a filter to identify portions of the region under test which have relatively high correlation values.

11. The system of Claim 2 wherein said automated polyp detection processor comprises a distance processor for aligning a distance template over the image and for computing a plurality of distance values, each of the plurality of distance values corresponding to a distance between a selected point on the distance template and a point on a bowel perimeter with each of the plurality of distance values computed using a different point on the bowel perimeter.

12 The system of Claim 11 wherein said automated polyp detection processor further comprises a comparison circuit for comparing each of the plurality of distance values.

13 The system of Claim 12 wherein said comparison circuit includes means for comparing each of the plurality of distance values by subtracting the values to provide a relative distance value.

14. The system of Claim 11 wherein said automated polyp detection processor further comprises a segmentor to extract pixels from the image to provide a region which includes a boundary between soft tissue and air in the colon and wherein said distance processor for aligns the distance template over the region provided by said segmentor.

15. The system of Claim 1 further comprising:

a detection system coupled to said digital bowel subtraction processor for detecting, in the digital images of the colon having contents digitally removed therefrom, regions having one or more characteristics similar to the characteristics of a polyp;

an indicator system for indicating on the images those regions detected by said detection system.

16. A method for performing a virtual colonoscopy comprising:

administering a contrast agent to a patient;

generating one or more bowel images of the patient to whom the contrast agent was administered; and

digitally subtracting the contents of the bowel shown in each of the one or more generated bowel images.

17. The method of Claim 16 wherein digitally subtracting the contents of the bowel comprises:

applying a threshold function to the bowel image;

performing a gradient analysis of the bowel image to define a first region corresponding to a wall region and a second region corresponding to a bowel contents region; and

digitally removing the second region from the bowel image to provide an image having the first region and not the second region.

18. The method of Claim 17 wherein performing a gradient analysis comprises:

identifying a portion of an image corresponding to an image transition region having a first portion which corresponds to bowel contents, a second portion which corresponds to bowel wall and a third portion disposed between the first and second portions which corresponds to a transition between the bowel contents and the bowel wall;

identifying a first shoulder region in the image transition region;

identifying a second shoulder region in the image transition region;

dilating the boundary first shoulder region applying a first threshold function to the bowel image;

applying a gradient to the analysis of the bowel image to define a first region corresponding to a wall region and a second region corresponding to a bowel contents region; and

digitally the second region from the bowel image to provide an image having the first region and not the second region.

19. The method of Claim 18 wherein identifying the second shoulder region includes:

dilating pixels around a portion of the image transition region corresponding to the second shoulder region;

comparing each of the pixel values to a gradient threshold value;

in response to a pixel value being less than the gradient threshold value setting that pixel value equal to a first predetermined value corresponding to a first one of a contents region and a wall region; and

in response to a pixel value being greater than the gradient threshold value, setting that pixel value equal to a second predetermined value corresponding to a second one of the contents region and the wall region.

20. The method of Claim 16 wherein digitally subtracting the contents of the bowel comprises:

generating a first pixel analysis map (PAM) from the image;

stepping the first PAM across the image in a raster pattern;

locating an air region in the image by examining a predetermined set of elements defined by the PAM;

searching an area around the air element to locate a bowel region adjacent the air region; and

subtracting the bowel contents from the image.

21. In an imaging system which represents an image by an array of pixels, a method of selecting pixels in the image representing bowel contents comprising:

forming a pixel analysis map comprising an array of pixels, with predetermined ones of the pixels in the map having a spatial relationship and a predetermined threshold value;

applying the pixel analysis map to the image;

comparing the values of the predetermined ones of the pixels in the pixel analysis map to pixels in the image and indicating whether the corresponding pixel in the image represents one of bowel contents or bowel wall;

setting values of pixels in the image corresponding to bowel contents to one of a pixel value corresponding to air and a pixel value corresponding to a bowel.

22. The method of Claim 21 wherein forming a pixel analysis map comprises:
defining a plurality of central pixels at the center of the pixel analysis map;
defining a plurality of boundary pixels disposed about the plurality of central pixels; and
defining a plurality of outer boundary pixels disposed about the plurality of boundary.

23. The method of Claim 22 wherein the comparing step comprises:
selecting a first pixel of the plurality of central pixels;
computing a difference value between a pixel in the image which is in a position adjacent to the position of the first pixel and an outer boundary pixel proximate the first pixel;
in response to the difference value being above a gradient threshold, setting the values of all pixels between the first pixel and the outer boundary pixel to a predetermined value.

24. The method of Claim 23 wherein the predetermined value corresponds to one of a air value or a bowel value.

25. A method for detecting structure in a CT image comprising:
obtaining a test structure template from a first CT image;
selecting a portion of a second CT image;
performing a convolution between the test structure template and the selected portion of the second CT image to produce a correlation matrix; and
identifying regions in the second image having values with a high correlation to characteristics of a polyp.

26. The method of Claim 25 wherein obtaining a test structure template comprises;
obtaining a first CT image which includes a structure of the type to be detected; and
excising the structure from the CT image to provide the test structure.

27. The method of Claim 26 wherein identifying regions in the second image comprises:
filtering values which are below a predetermined correlation threshold value; and
designating a region of an image as having a likelihood of containing a structure with a

shape which is similar to the shape of the test structure;

28. The method of Claim 26 wherein the test structure template corresponds to a polyp template and the structure of the type to be detected in the first CT image corresponds to a polyp.

29. A method for detecting polyps comprising:

moving a test element along a boundary of a bowel;

tracking a path defined by the movement of the test element;

detecting changes in direction of the test element in the path;

classifying bowel features based upon the path of the test element and the changes in direction of the test element.

30. The method of Claim 29 wherein detecting changes in direction of the test element in the path comprises:

computing changes in slope of the path defined by the test element;

marking a point at each location at which the direction of the slope of the path changes;

computing distances between each of the marked points; and

computing a ratio value using each of the distances.

31. The method of Claim 30 wherein classifying bowel features based upon the path of the test element and the changes in direction of the test element comprises identifying bowel features using the ratio value.

32. The method of Claim 31 wherein the test element is provided having a circular shape.

33. The method of Claim 31 wherein the test element is provided having a spherical shape.

34. A method for detecting polyps comprising:

applying a template to a region of an image which contains a bowel perimeter;

computing a plurality of distances between the template and the bowel perimeter, each of

the plurality of distances corresponding to a distance from at least one point on the template to one of a plurality of points on the bowel perimeter; and

determining whether the distances are equal.

35. The method of Claim 34 wherein, in response to the distances being equal, identifying the image region as containing a structure having a shape which is similar to the shape of the template.

36. The method of claim 34 wherein applying a template to a bowel perimeter comprises:

segmenting a bowel image to produce to an image from which pixels which do not form the bowel perimeter have been filtered.

36. The method of claim 35 wherein computing a plurality of distances between the template and the bowel perimeter comprises computing the distances between points on a perimeter of the template and points on the perimeter of the bowel.

37. The method of Claim 36 wherein determining whether the distances are equal comprises computing a standard deviation between the distances.

38. A method for inserting a mucosa layer comprising:

applying a gradient operator to an image from which bowel contents have been digitally extracted to identify pixels corresponding to a boundary between bowel wall and non-bowel wall regions in the image;

smoothing the boundary by applying a constrained gaussian filter to the pixels which form the boundary, wherein the smoothing takes place over a predetermined width along the boundary.

39. The method of Claim 38 wherein the predetermined width corresponds to a width of less than ten pixels.

40. The method of Claim 39 wherein the predetermined width corresponds to a width in the

range of two to five pixels.

41. The method of Claim 40 wherein the predetermined width corresponds to a width of three pixels.